

91-03080/

EXECUTIVE SUMMARY

AN ICE JAM FLOOD STUDY
FOR
SIMONDS
PHASE II

PREPARED FOR

NEW BRUNSWICK DEPARTMENT OF
MUNICIPAL AFFAIRS AND ENVIRONMENT

PREPARED BY

SUB SURFACE SURVEYS
F1784 / F1856

FEBRUARY, 1989

1. INTRODUCTION

Between April 1 and 4 of 1986, an ice jam formed on the Saint John River at the upstream end of Upper Becaguimec Island. This caused a great increase in the water levels behind the jam and flooding occurred at Simonds, New Brunswick. The road had to be closed, families had to be evacuated, and there was flood damage to several homes and businesses in the area.

The Saint John River, between Stickney and Hartland has been a prime location for ice jam lodgement. River observations over the years show frequent ice lodgement at Stickney, Peel Island and Upper Becaguimec Island. The jamming which occurred in 1986 was the most severe on record, lasting the longest time and causing water levels nearly 2 m (6.6 ft) higher than previous maximums. The jam remained in place longer than normal due to the backwater effect from a winter jam which had formed at Sproule's Island and had frozen in place (N.B. Subcommittee on River Ice, 1987).

As a result of serious ice-related events on the Saint John River, in particular the 1986 ice jam flooding at Simonds and the 1987 ice jam flood at Perth-Andover, a Working Group and a Review Committee were appointed to undertake a thorough study of the flooding problem. The Working Group and Review Committee were given the mandate to make recommendations for action which could be taken to reduce the risk of flooding and the subsequent related damages.

These committees developed a phased program, beginning with a study (Phase I) to collect and review existing information relevant to the flooding problem in the area. The first study

included an evaluation of the requirements for field investigations and the carrying out of those investigations. This study was completed in June, 1988 by Gemtec.

Objectives

Sub Surface Surveys was commissioned to conduct the present study as Phase II of the study program. The objectives of this study are to identify various feasible structural and non-structural flood damage reduction measures, and to estimate the costs and where possible, the benefits of each. The details of the requirements of this study are outlined in the Terms of Reference dated June 1988.

Study Area

The Study Area included the Saint John River Valley from the Lower Presque Isle Island to the Upper Becaguimec Island, below the 1986 flood level (Map 1). This area comprises the extent of the area affected by flooding from the 1986 ice jam flood.

Authorization

Sub Surface Surveys has undertaken this study for the New Brunswick Department of Municipal Affairs and Environment. The study has been completed in consultation with the Working Group, which was comprised of representatives from the Department of Municipal Affairs and Environment, the New Brunswick Department of Transportation, the New Brunswick Department of Agriculture and the New Brunswick Electric Power Commission.

STUDY AREA

NEW BRUNSWICK

STUDY AREA
6 km

SIMONDS

St Thomas

Avondale

Wilmot

SIMONDS PARISH
WAKEFIELD PARISH

Upper Waterville

Jacksontown

Waterville

Flagstaff Hill

1 km 0 1 km

STUDY AREA
SIMONDS

SUB SURFACE SURVEYS
CONSULTING ENGINEERS

SCALE: 1 : 50 000

DRAWN BY: MA

DRAWING No.: MAP 1

DATE: 88 11 21

2. METHODOLOGY

This study involved a multi-disciplinary approach with each discipline being interrelated with the overall analysis of the ice jam flood study. The specific tasks in the various disciplines are summarized below.

In addition to this Executive Summary, a Summary Document and a comprehensive Technical Background Report have been prepared. These were submitted under separate cover to the Working Group and contain all supporting data and analyses pertinent to the findings of the study.

Planning

To develop appropriate flood protection measures, a comprehensive inventory of land use and structures within the Study Area was compiled. Based on this inventory, the existing zoning, current regulations (Community Planning Act), land use control measures and damage potential from flooding were reviewed. These were ranked by flood damage potential to provide an effective method for evaluating protection required for an individual structure or groups of structures.

Hydrotechnical

The hydrotechnical analysis considered the various drainage systems within the area and how they respond to rapid increases in the River level. The objective of these investigations was to evaluate the effectiveness of the use of flap gates on the culverts emptying into the Saint John River. The frequency of ice jam flooding in the Study Area was also addressed with the objective of assigning a frequency of recurrence to the 1986 flood event.

Geotechnical

The nature of bank erosion and stability was reviewed as it pertains to both normal and elevated river flows. The permeability of the subsurface in the Study Area was determined by field trials in order to evaluate the impact of through-ground flow. Criteria were developed which can be used to measure the extent of protection required.

Engineering

A range of possible flood control measures were compiled and evaluated. Preliminary conceptual designs were prepared, specific to the Study Area. The costs of the various design options were determined and the most suitable of these were subjected to an economic analysis.

Economics

A benefit-cost analysis was conducted to evaluate the selected alternatives in terms of cost and the degree of flood protection provided. The analysis considered the impact of flood protection on both the private and public sectors, and evaluated the relative benefits to each.

3. CONCLUSIONS AND RECOMMENDATIONS

The Technical Background Report details the methodology used in defining the aspects of the flooding and associated remedial measures that would be appropriate for Simonds.

The Summary Document presents the synopsis of the findings of the Technical Background Report. It is suggested that the complete documentation be reviewed as additional actions and supporting data are included that may be significant.

PLANNING

- 1) It is recommended that flood zones be established and controlled by enactment of Flood Risk Area Guidelines for Simonds.
- 2) Incentives should be considered for the existing residents to assist them in either floodproofing or relocating.
- 3) Development should be discouraged within the defined flood zones.
- 4) Official disclosure of the flood risk should be made to notify potential developers within the flood risk area.

HYDROTECHNICAL

- 5) Culverts have sufficient capacity under backflow conditions to contribute significantly to flooding.

- 6) It is concluded that culverts should be blocked by flap gates, to protect against the inward flow during flooding.

GEOTECHNICAL

- 7) It was concluded that the flood water movement in Simonds by through-ground flow could be a significant factor in the flooding.
- 8) It is recommended that a study should be undertaken to define the response of the groundwater table to the rise in the River water level.
- 9) Six (6) sites of riverbank erosion were identified and it was concluded that one (1) site is in need of immediate action.
- 10) Remedial measures recommended for slope stabilization are presented in the Summary Document.

REMEDIAL MEASURES

- 11) A number of potential remedial measures for flood protection were reviewed from which ten (10) selected measures are recommended and were analyzed in detail.

ECONOMICS

- 12) The selected remedial measures are presented in Table 1 with the associated costs and the ranking based on the benefit-cost ratios developed.

Table 1
Cost Estimates and Benefit-Cost Ratios for Remedial Measures

Remedial Measure	Remedial measures	Benefit-Cost Ratio
	Cost	
1) Earth dike	\$530,000	0.25
7) Elevate structures affected by overland flow	\$530,000	0.15
8) Elevate to max of 1 m, relocate others	\$660,000	0.12
10) Relocate structures affected by overland flow	\$1,180,000	0.11
9) Elevate commercial, relocate others	\$1,050,000	0.08
2) Concrete floodwall	\$1,800,000	0.08
5) Raise roads	\$1,840,000	0.07
6) Raise roads and elevate structures	\$2,040,000	0.07
3) Sheetpile floodwall	\$3,400,000	0.04
4) Sheetpile floodwall to cutoff	\$14,590,000	0.01

Note: • Remedial measures listed by decreasing benefit-cost ratio.
• Interest rate = 10%, base flood of 100 year return assumed.

13) It is concluded that:

- Notwithstanding the fact that the benefit-cost ratio is less than one, maximizing the dollar value of benefits per dollar spent leads to the selection of the remedial measure of an earth dike, as does maximizing the net present value of the remedial project.

- If the earth dike is excluded on the grounds it carries negative externalities, the most efficient remedial measure becomes the floodproofing option of elevating all structures which were affected by overland flow.
 - The ranking of measures is insensitive to the choices of the discount rate and the flood return period.
 - The construction of the remedial measure will have positive effects on employment and incomes in the Province.
- 14) Non-economic issues such as aesthetics, social, cultural and planning considerations may alter the ranking of the remedial measures which have been assessed from a solely economic perspective.

RESUME ADMINISTRATIF

**ETUDE SUR LES INONDATIONS CAUSEES PAR LES EMBACLES
POUR
SIMONDS
PHASE II**

PREPARE POUR

**LE MINISTERE DES AFFAIRES MUNICIPALES
ET DE L'ENVIRONNEMENT**

PAR

SUB SURFACE SURVEYS

F1784 / F1856

FEVRIER 1989

(Translated from English by McLaughlin Translation Company Ltd.)

1. INTRODUCTION

Du 1^{er} au 4 avril 1986, un embâcle s'est créé sur le fleuve Saint-Jean à l'extrémité en amont de l'île Upper Becaguimec. Cette situation a beaucoup fait monter les niveaux d'eau en arrière de l'embâcle, ce qui a produit des inondations à Simonds, Nouveau-Brunswick. Le chemin a dû être fermé, des familles ont dû être évacuées, et plusieurs maisons et commerces dans la région ont subi des dommages causés par les inondations.

Le fleuve Saint-Jean, entre Stickney et Hartland, a été un des principaux endroits où des glaces se sont accumulées. Les observations de la rivière au cours des années montrent des accumulations fréquentes de glace à Stickney, Peel Island et à l'île Upper Becaguimec. L'embâcle qui s'est produit en 1986 a été le plus grave jamais enregistré; c'est l'embâcle qui a duré le plus longtemps, faisant monter les niveaux d'eau de près de 2 mètre (6.6 pieds) au-delà des maximums précédents. L'embâcle est resté plus longtemps que la normale en raison des effets de la longueur du remous d'un autre embâcle survenu pendant l'hiver qui s'était formé à l'île Sproule et avait gelé sur place (sous-comité du Nouveau-Brunswick sur les glaces du fleuve, 1987).

A la suite de ces événements causés par la glace sur le fleuve Saint-Jean, en particulier l'inondation à Simonds en 1986 et l'inondation à Perth-Andover en 1987 causées par les embâcles, un groupe de travail et un comité de révision ont été nommés pour entreprendre une étude approfondie du problème des inondations. Ce groupe de travail et le comité de révision ont reçu le mandat de recommander des mesures qui pourraient être prises pour réduire les risques d'inondation et les dommages connexes subséquents.

Ces comités ont élaboré un plan d'étude à plusieurs phases, commençant par une étude (phase I) en vue de recueillir et

d'étudier les données pertinentes actuelles relatives aux problèmes des inondations dans la région. La première étude comportait une évaluation des critères des études sur place ainsi que l'étude proprement dite. Cette étude a été achevée en juin 1988 par Gemtec.

Objectifs

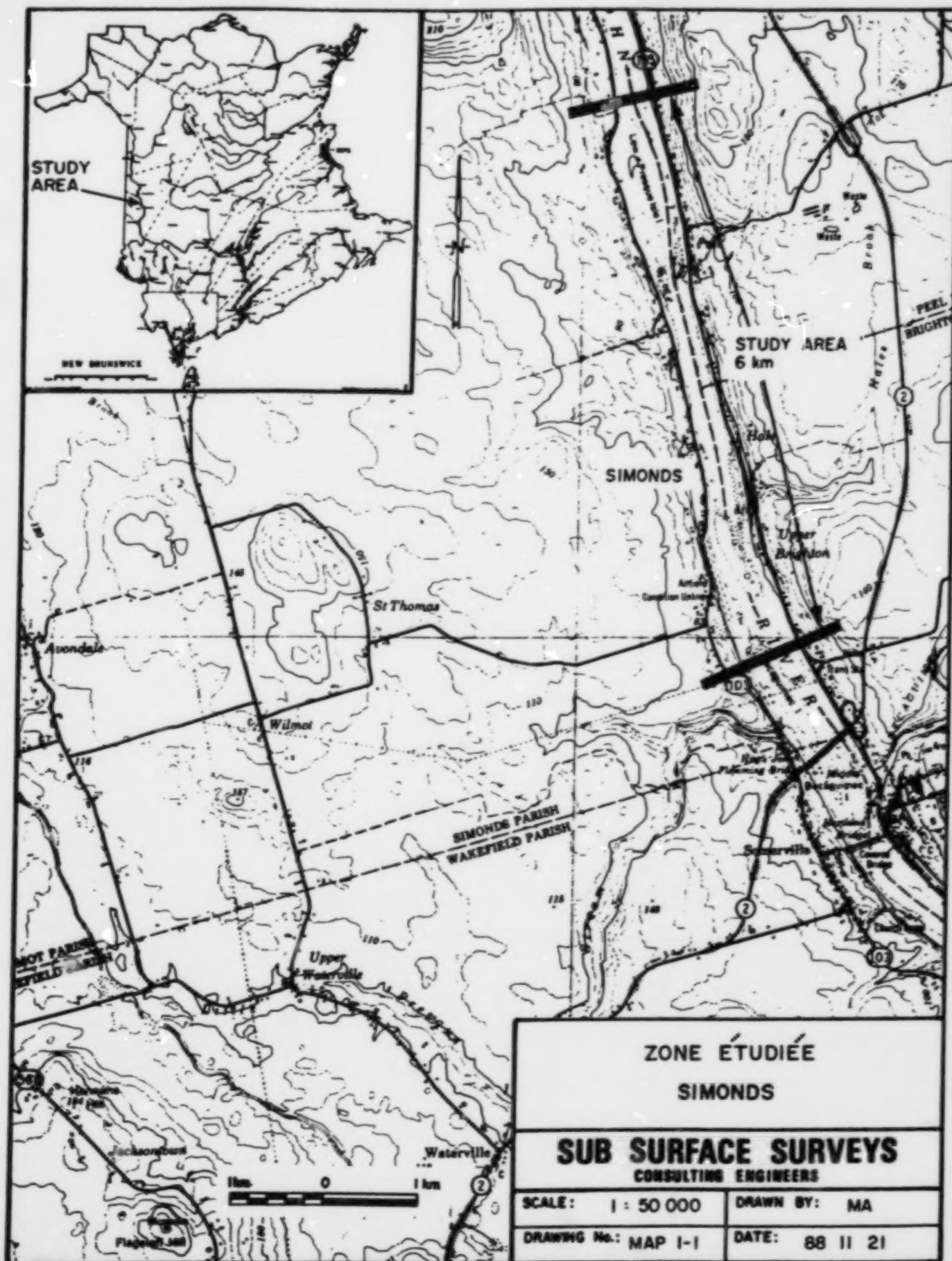
On a retenu les services de Sub Surface Surveys pour effectuer l'étude actuelle qui constitue la deuxième phase du plan d'étude. Les objectifs de cette étude sont d'identifier les diverses mesures structurales et non structurales de réduction des dommages causés par les inondations, d'établir les coûts approximatifs, et dans la mesure du possible, les bienfaits de chaque mesure. Les critères détaillés de cette étude sont expliqués dans les attributions datées de juin 1988.

Zone étudiée

La zone étudiée comprenait la vallée du fleuve Saint-Jean, à partir de l'île Lower Presque Isle jusqu'à l'île Upper Becaguimec, en-deçà du niveau d'inondation de 1986, (carte 1). Cette région comprend la superficie de la zone inondée lors de l'inondation causée par l'embâcle de 1986.

Autorisation

Sub Surface Surveys a entrepris cette étude pour le ministère des Affaires municipales et de l'Environnement. L'étude a été effectuée en consultation avec le groupe de travail qui se composait de représentants du ministère des Affaires municipales et de l'Environnement, du ministère des Transports du Nouveau-Brunswick, du ministère de l'Agriculture du



Nouveau-Brunswick et de la Commission d'Énergie électrique du Nouveau-Brunswick.

2. MÉTHODOLOGIE

Cette étude a mis un accent multidisciplinaire sur les différents aspects, chaque discipline étant interreliée à l'analyse globale de l'étude des inondations causées par les embâcles. Les tâches précises sont résumées ci-dessous.

Outre ce Résumé administratif, un Document sommaire et un Rapport technique général exhaustif ont été préparés. Ces documents, qui ont été soumis sous pli séparé au groupe d'étude, contiennent toutes les données d'appui et analyses pertinentes par rapport aux conclusions de l'étude.

Planification

Pour élaborer des mesures adéquates de protection contre les inondations, un inventaire exhaustif de l'utilisation des terrains et des structures dans la zone étudiée a été compilée. Selon cet inventaire, le zonage de développement actuel, les règlements actuels (loi sur l'urbanisme), les mesures de contrôle et l'utilisation des terres et les dommages éventuels pouvant résulter de l'inondation ont été examinés. Ces aspects ont été classés en fonction des risques de dommages provoqués par les inondations afin d'évaluer efficacement le degré de protection exigé pour les structures individuelles ou les groupes de structures.

Hydrotechnique

L'analyse hydrotechnique a examiné les divers systèmes de drainage dans la région et la façon dont ils réagissent à la

montée rapide du niveau du fleuve. Ces enquêtes avaient pour but d'évaluer l'efficacité de l'utilisation des vannes à charnière et des ponceaux se déversant dans le fleuve Saint-Jean. La fréquence des inondations causées par les embâcles dans la zone étudiée a été examinée en vue d'établir une intervalle de récurrence par rapport à l'inondation de 1986.

Géotechnique

La nature de l'érosion de la rive et la stabilité ont été examinées puisqu'elles sont reliées aux écoulements élevés et normaux du fleuve. La perméabilité de la sous-surface dans la zone étudiée a été évaluée par des essais sur place afin d'évaluer l'impact de l'écoulement souterrain. Des critères ont été établis afin de mesurer le degré de protection exigé.

Ingénierie

Différentes mesures possibles de contrôle des inondations ont été compilées et évaluées. Des plans conceptuels préliminaires ont été préparés pour la zone étudiée. Le coût des diverses options en matière de conception a été déterminé et les options les plus convenables ont été soumises à une analyse économique.

Faisabilité

Une analyse avantages-coût a été effectuée pour évaluer les solutions choisies par rapport au coût et au degré de protection assuré contre les inondations. L'analyse a examiné l'impact de la protection contre les inondations sur les secteurs public et privé, et évalué les avantages relatifs de chacun.

3. CONCLUSIONS ET RECOMMANDATIONS

Le Rapport technique général décrit en détail la méthode utilisée pour définir les aspects des inondations et les mesures de redressement pertinentes qui conviendraient pour Simonds.

Le Document sommaire présente un résumé des constatations contenues dans le Rapport technique général. On propose que toute la documentation soit étudiée puisque d'autres mesures et données à l'appui qui pourraient être pertinentes sont présentées.

PLANIFICATION

- 1) Il est recommandé que les zones inondables soient établies et contrôlées par l'adoption de lignes directrices sur les zones inondables pour Simonds.
- 2) Il faudrait envisager des mesures d'encouragement pour aider les résidents à se protéger contre les inondations ou à se reloger.
- 3) Il faudrait décourager les aménagements dans les zones inondables définies.
- 4) Le risque d'inondation devrait être divulgué officiellement pour aviser les promoteurs éventuels dans la zone qui pourrait être inondée.

HYDROTECHNIQUE

- 5) Les ponceaux ont suffisamment de capacité en cas de contre-courant pour contribuer de façon significative aux inondations.

- 6) On conclut que les ponceaux devraient être bloqués par des vannes à charnière pour assurer une protection contre l'écoulement interne pendant les inondations.

GÉOTECHNIQUE

- 7) Il a été conclu que le mouvement de l'eau des inondations dans la région par les écoulements souterrains pourrait être un facteur déterminant des inondations.
- 8) Il est recommandé qu'une étude soit entreprise pour définir la réaction de la nappe d'eau souterraine par rapport à la montée du niveau d'eau du fleuve.
- 9) Six (6) lieux d'érosion de la rive du fleuve ont été identifiés et il a été conclu que un (1) de ces lieux justifient la prise de mesures immédiates.
- 10) Les mesures de redressement recommandées pour la stabilisation des pentes sont présentées dans le Document sommaire.

MESURES DE REDRESSEMENT

- 11) Un certain nombre de mesures de redressement potentielles pour la protection contre les inondations ont été examinées, dont dix (10) ont été choisies, recommandées et analysées en détail.

FAISABILITÉ

- 12) Les mesures de redressement choisies sont présentées au tableau 1, ainsi que les coûts connexes et elles sont

classées selon les rapports avantages-coût établis.

13) Il est conclu que :

Néanmoins le fait que le rapport avantage-coût est inférieur à un, la maximisation de la valeur monétaire des avantages par dollar dépensé mène à la sélection du digue de terre comme mesure de redressement, comme c'est aussi le cas pour la maximisation de la valeur actuelle nette du projet de redressement.

Tableau 1

Estimation des coûts et rapport avantages-coût pour les mesures de redressement

Mesure de redressement	Mesures de redressement Coût	Rapport Avant.-coût
1) Digue de terre	530 000 \$	0.25
7) Élévation des structures affectées par les écoulements de surface	530 000 \$	0.15
8) Élévation à 1 m max., relogement des autres	660 000 \$	0.12
10) Relogement des structures affectées par les écoulements de surface	180 000 \$	0.11
9) Élévation des propriétés commerciales, relogement des autres	1 050 000 \$	0.08
2) Mur en béton	1 800 000 \$	0.08
5) Soulèvement des chemins	1 840 000 \$	0.07
6) Élévation des chemins et des structures	2 040 000 \$	0.07
3) Palplanche	3 400 000 \$	0.04
4) Palplanche jusqu'au barrage souterrain	14 590 000 \$	0.01

Note: • Mesures de redressement énumérées en fonction du rapport décroissant avantages-coût.
• Taux d'intérêt = 10 %, base d'inondation supposant une période de récurrence de 100 ans.

- Un examen des autres avantages provenant de l'augmentation des autres coûts mène à la sélection des mesures de redressement telles que le digue de terre.
 - Si la digue de terre est exclue parce qu'elle a des effets négatifs, la mesure de redressement la plus efficace est celle qui consiste à élever toutes les structures affectées par les écoulements de surface.
 - Le classement des mesures ne tient compte ni des choix du taux d'escompte, ni de la période de récurrence des inondations.
 - La mise en oeuvre d'une mesure de redressement aura des effets positifs sur l'emploi et les revenus dans la province.
- 14) Les questions non économiques telles que l'esthétique, les aspects sociaux, culturels et la planification peuvent modifier le classement des mesures de redressement qui ont été évaluées à partir d'une perspective économique seulement.

SUMMARY DOCUMENT

**AN ICE JAM FLOOD STUDY
FOR
SIMONDS
PHASE II**

PREPARED FOR

**NEW BRUNSWICK DEPARTMENT OF
MUNICIPAL AFFAIRS AND ENVIRONMENT**

PREPARED BY

SUB SURFACE SURVEYS

F1784/F1856

FEBRUARY 1989

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1.0 INTRODUCTION

Between April 1 and 4 of 1986, an ice jam formed on the Saint John River at the upstream end of Upper Becaguimec Island. This caused a great increase in the water levels behind the jam and flooding occurred at Simonds, New Brunswick. The road had to be closed, families had to be evacuated, and there was flood damage to several homes and businesses in the area.

The Saint John River, between Stickney and Hartland has been a prime location for ice jam lodgement. River observations over the years show frequent ice lodgement at Stickney, Peel Island and Upper Becaguimec Island. The jamming which occurred in 1986 was the most severe on record, lasting the longest time and causing water levels nearly 2 m (6.6 ft) higher than previous maximums. The jam remained in place longer than normal due to the backwater effect from a winter jam which had formed at Sproule's Island and had frozen in place (N.B. Subcommittee on River Ice, 1987).

In general there are two types of flood events; for the purposes of this Study, the following definitions have been applied:

- Open water flooding is the result of high flows in a river which exceed its bankfull capacity. This causes the rising waters to extend into the floodplain; and
- Ice jam floods are the result of the sudden stoppage of ice moving on a river during breakup. The stoppage causes a temporary dam with a rapid rise in water level behind it. The water levels associated with an ice jam flood are usually much higher than would occur during an open water flood.

As a result of serious ice-related events on the Saint John River, in particular the 1986 ice jam flooding at Simonds and the 1987 ice jam flood at Perth-Andover, a Working Group and a Review Committee were appointed to undertake a thorough study of the flooding problem. The Working Group and Review Committee were given the mandate to make recommendations for action which could be taken to reduce the risk of flooding and the subsequent related damages.

These committees developed a phased program, beginning with a study (Phase I) to collect and review existing information relevant to the flooding problem in the area. The first study included an evaluation of the requirements for field investigations and the carrying out of those investigations. This study was completed in June, 1988 (Gemtec, 1988).

1.1 Objectives

Sub Surface Surveys was commissioned to conduct the present study as Phase II of the study program. The objectives of this study are to identify various feasible structural and non-structural flood damage reduction measures, and to estimate the costs and where possible, the benefits of each. The details of the requirements of this study are outlined in the Terms of Reference dated June 1988.

In addition to this Summary Document, a comprehensive Technical Background Report has been prepared. This Report was submitted under separate cover to the Working Group, and contains all supporting data and analyses pertinent to the findings of the Study.

1.2 Study Area

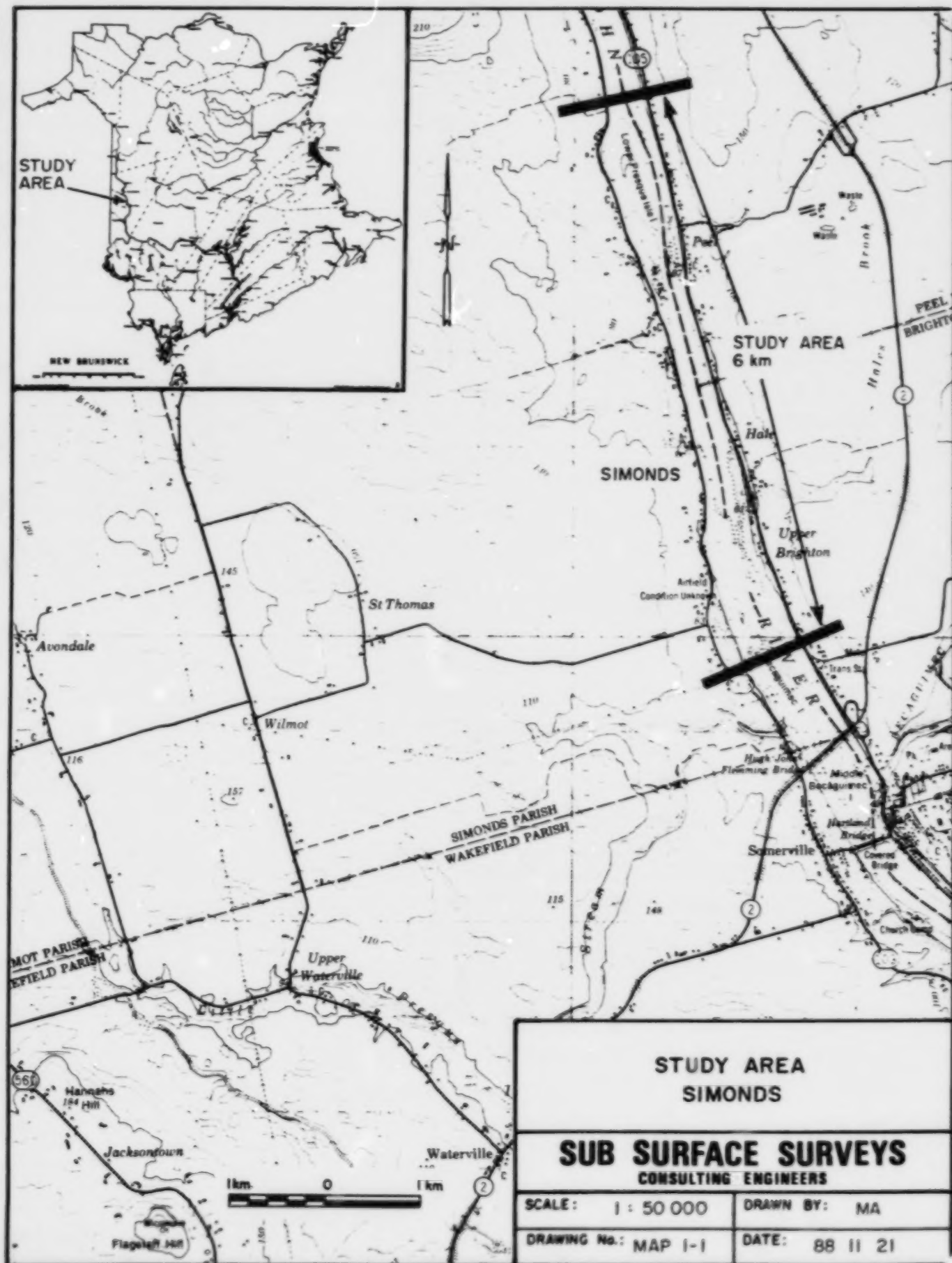
The Study Area included the Saint John River Valley, from the Lower Presque Isle Island to the Upper Becaguimec Island, below the 1986 flood level (Map 1-1). This area comprises the extent of the area affected by flooding from the 1986 ice jam flood.

1.3 Authorization

Sub Surface Surveys has undertaken this study for the New Brunswick Department of Municipal Affairs and Environment. The study has been completed in consultation with the Working Group, comprised of representatives from the Department of Municipal Affairs and Environment, the New Brunswick Department of Transportation, the New Brunswick Department of Agriculture and the New Brunswick Electric Power Commission.

2.0 BACKGROUND INFORMATION

The Saint John River has been subject to extensive flooding along its length. Flooding has been very serious, warranting the establishment of the Saint John River Forecast Centre in 1973, which provides a warning of high water levels and flooding events. The Centre provides estimates of open water levels on a daily basis during flood conditions but does not attempt to forecast the occurrence of ice jams or ice jam related flood levels. The Centre does monitor ice conditions and maintains a group of observers. The start of ice breakup is monitored and warnings are issued to areas which are prone to ice jam flooding.



There are several reports on the extent and nature of flooding in the upper reaches of the Saint John River including such major reports as *Saint John River, Analysis of 1976 Ice Jams* (Acres, 1976), *The April 1986 Ice Jam at Simonds, N.B.* (N.B. Subcommittee on River Ice, 1987) and *1987 Saint John River Flooding* (Acres, 1988).

2.1 Flood Events

There has been some minor flooding in the past from high open water levels at Simonds. These are relatively minor events and did not cause serious flooding. The banks of the River at Simonds are quite high and would only be overtopped by extreme water levels in the river. The present study does not investigate the nature or extent of past open water flood events.

During the 1976 ice jams on the Saint John River, the water levels at Simonds rose due to ice jams in the River. The levels reached a maximum of 48.1 m (157.8 ft), and held for about 4 to 6 hours at the peak levels (Acres, 1976). These levels were not sufficient to cause problems at Simonds, although the level came close to the crest of the road, which has a low point at 48.5 m (159.1 ft).

The ice jam flooding of April 1 to 4, 1986 is the only major flooding event which has been recorded for the Simonds area.

In April 1986, the combination of hydraulic, climatic and ice conditions in the Simonds to Hartland area resulted in the formation of a severe ice jam at the upstream end of the Upper Becaguimec Island. The jam remained in place longer than normal due to the backwater effect from an earlier winter jam which had formed at Sproule's Island and had frozen in place (N.B. Subcommittee on River Ice, 1987). This resulted in high water

levels behind the jam which flooded over the road (Route 103) on the west side of the Saint John River. The high water forced the evacuation of several families and caused damage to several structures. The maximum water level recorded for this event was 51.5 m (167.8 ft).

In 1987, there was ice jamming in the Saint John River and severe flooding occurred in the Village of Perth-Andover. The ice run in the Beechwood to Mactaquac reach jammed in several locations, including the Upper Becaguimec Island. The water level at Simonds rose during this jam to reach a maximum level of 49.2 m (161.4 ft). This level was 1.9 m (6.2 ft) lower than the 1986 maximum, but high enough to cause the road to be closed, and to nearly reach the door sills of some houses in Simonds (Acres, 1988).

The flooding at Simonds in 1986 did not occur at the same time as other major jamming in the River, and therefore appears to be a random event related to the variance of flow and breakup in the River.

3.0 FLOODPLAIN DEVELOPMENT CONTROL IN SIMONDS

3.1 Land Use and Building Inventory

To develop appropriate flood protection measures, a comprehensive inventory of land use and structures within the flood area was compiled. The Study Area included riverbank areas below the 1986 flood level from the Lower Presque Isle Island to Upper Becaguimec Island (Map 1-1). The inventory was compiled by collating information from previous reports and studies and air photos. This information was then supplemented by:

- field surveys (air and highway);

- input from meetings with local residents; and
- conversations with local officials.

A land use inventory of the Study Area revealed the following uses:

- RESIDENTIAL: single-detached, duplexes and mobile homes;
- AGRICULTURAL: barns and storage sheds;
- INSTITUTIONAL: churches, cemeteries, and organizational meeting places;
- INDUSTRIAL AND COMMERCIAL: potato storage sheds and automotive repair shops;
- HAZARDOUS PRODUCT STORAGE: potato storage sheds and automotive repair shops; and
- TRANSPORTATION: Highways, rural collectors, secondary roads and railways.

The impact of potential flooding on these land uses includes, but is not necessarily limited to:

- the loss of human or animal life and/or injury;
- property damage to residential and agricultural buildings;
- property damage and loss of revenue for commercial and industrial establishments;

- immediate danger (fires, explosions) and long term and long range environmental problems affecting downstream surface and groundwater quality from commercial establishments or storage buildings housing hazardous substances;
- the isolation of local residents and the prevention of access to facilities and essential services located outside the flooded area;
- property damage and loss of economic revenue for both the Canadian Atlantic Railway (CPR) and the economic activities dependent upon rail service; and
- property damage or loss of land to erosion by flood waters.

3.2 Existing Development Zoning

The Provincial Department of Municipal Affairs and Environment monitors development in unincorporated areas, such as Simonds, within the Province. Therefore, there is no municipal plan, zoning by-law, or control of land use as exists for municipalities. The area consists mainly of residential-agricultural land use, with a few residential-commercial establishments.

The Community Planning Act contains several relevant sections dealing with land use control within unincorporated areas. For example, the Lieutenant-Governor in Council, on the recommendation of the Minister, may designate any unincorporated area for the purpose of the adoption of an unincorporated area plan (Section 28(1)).

The adoption of an area plan does not commit the Province to undertake any proposal suggested therein or outlined, but shall

prevent the undertaking of any development by the Province or an individual in any manner inconsistent or at variance with any proposal or policy outlined or suggested in the area plan. Map 3-1 (located at the end of the Document) illustrates the land use and existing development in the Simonds area.

3.3 Land Use Control Options

It is recommended that the regulatory measures outlined below be considered to reduce damage caused by flooding in the Simonds area.

- (1) The maximum historic case of the 1986 flood elevation should be used to define the flood risk zone. There has not been a hydrotechnical study of the Simonds area to determine the 1 in 20 and the 1 in 100 year open water flood levels. Such a study is not recommended because flooding in Simonds is historically ice related and not due to open water floods.
- (2) Incentives could be considered for residents within the flood risk zone to help them floodproof existing structures to conform to minimum levels of flood protection. This would eliminate or reduce future flooding compensation expenditures.
- (3) Incentives could be considered for residents within the flood risk zone to assist them in relocation if this action is deemed appropriate.
- (4) Development could be discouraged within the flood risk zone by making it conditional on the provision of appropriate floodproofing measures.

- (5) An official disclosure of flood risk could be provided to any individual transferring, purchasing, or leasing property within the flood risk zone. It is felt that appropriate land use controls in the flood zone would be achieved effectively by use of Flood Risk Area Guidelines tailored specifically to the flood protection needs of the Study Area.

The Flood Risk Area Guidelines should provide Engineering standards, designs, and techniques for all development in the flood risk area, and prohibit any development except in accordance with the Guidelines.

The Guidelines may prohibit development that will obstruct or interfere with the normal floodway or free flow of flood waters during a flood period. The Guidelines may require that all development in a flood risk area or in any portion thereof, should be carried out so as not to reduce the flood water storage capacity of such area.

A proposed Flood Risk Area Guideline is provided in Appendix A of the Technical Background Report.

4.0 HYDROTECHNICAL CONSIDERATIONS

The Saint John River Basin is the largest basin in the Province. The River has a total drainage area of 55,143 km² (21,300 mi²), and flows from Southern Quebec and Northern Maine, to the Bay of Fundy. Over half the drainage basin lies within New Brunswick. The mean annual precipitation varies from 900 mm (35.4 inches) at the headwaters to 1200 mm (47.2 inches) at the Bay of Fundy. The River generally experiences two flow peaks; the first occurs during the spring runoff in April to May, and the second occurs during periods of increased rainfall in October and November.

The spring peak, which results from a combination of snowmelt and high precipitation, normally leads to the highest peak.

The spring event usually occurs shortly after the breakup of the ice cover on the River. When abnormally high flow occurs early in spring, a mechanical breakup of competent ice cover results. Heavy ice runs and jamming can occur, causing a rapid rise in water levels in the River. This can lead to flooding of land adjacent to the River and damage to roads, houses, bridges and other structures.

4.1 Local Drainage

The Simonds drainage system is comprised of four (4) culverts which carry flow under Route 103 to the River. The flow from the drainage subbasins in Simonds is termed the local inflow. If remedial measures were constructed to cut off the connection between the subbasins and the River, then the contained local inflow could lead to flooding of Simonds independent of the River.

The inverts of these culverts are at elevations very close to the normal summer River level. In the event of high water levels in the River, water would back up through the culverts and contribute to flooding in the Simonds area.

The volume of runoff based on the calculated average runoff is sufficient to cause backing up of water and some flooding if the culverts were blocked by flap gates. Storms and precipitation on the subbasins were shown to contribute to a much higher runoff, which could lead to extensive flooding behind the culverts.

A storage volume curve is required to relate the level of water in the Simonds area to the volume of water upstream of each

culvert. This form of detailed relationship is not available for Simonds and therefore for the requirements of this Study it was impractical to determine the flood level which would result from the runoff volumes determined.

4.2 Flood Stage Frequency Analysis

The flood frequency is an important component of the assessment of the cost and benefits of remedial measures. It is used to determine the present value of the benefits which would arise from preventing the inundation of an area by flood waters.

For rivers subject to flooding due only to high open water, the water level frequency curve can readily be determined from the flow frequency and water level-discharge curves. Modelling of the water level profile in the River can be performed to determine the expected water level for the 1 in 20 year and the 1 in 100 year return period open water flood.

The probability of an ice jam occurring cannot be determined with the current methodologies available anywhere in the world. It is important, however, to approximate a probability (frequency) for the purposes of the economic analysis. *Therefore, for the purposes of this study, it was decided to arbitrarily assign a return period of 100 years to the water level observed during the 1986 event, this is termed the "Base Flood".* A range of return periods between 5 years and 200 years are also examined to determine the sensitivity of the conclusions in the economic analysis to the return period.

Although an analysis can be made of the frequency of the riverflow at the time of breakup, this does not provide guidance to whether ice jamming will occur or where it will lodge.

5.0 GEOTECHNICAL ENGINEERING CONSIDERATIONS

5.1 Soil Conditions

The typical soil stratigraphy in the Simonds region can be described as two distinct zones. These zones are generally defined as a surficial deposit which varies from a brown silty sand, to sand, to sandy gravel which then overlies a very thick deposit of coarse sand and gravel. The coefficient of permeability of each of these layers was determined for the purposes of this study as distinct units.

5.2 Through-ground Flow

The groundwater regime, in general, is influenced by precipitation, infiltration and evaporation. This situation can change when over shorter or longer periods of time, other factors impose a major effect on the groundwater region. One of the common factors which influences the groundwater regime is the presence of natural rivers and lakes. In this case, the variable surface water conditions induced by meteorological events are superimposed on the more stable groundwater regime of the river basin. These surface water events may be of such a high intensity (such as a flood), that its impact becomes a short-term, but dominant factor in controlling the groundwater regime.

In the present Study, the available data is inadequate to determine a reasonable value for the range of influence of the through-ground flow. This range is critical for flood damage assessment. The only data which can be used to perform an order of magnitude semi-empirical analysis is the data from piezometers in the vicinity of the Saint John River obtained in April of 1988 (GEMTEC, 1988). These data give the groundwater table readings for changing water levels in the River over a period of 15 hours.

It should be noted, however, that the number of wells and their locations are inadequate to determine the range (inland distance) over which there is a relationship between the water level in the River and the groundwater level. These data were not collected simultaneously (with respect to time), thus introducing further temporal errors to the semi-empirical analysis.

The review of the limited available data and results of the simplified semi-empirical analysis performed for the Perth-Andover portion of this Study (SSS 1988), indicates that the low-lying areas adjacent to the Saint John River will be flooded due to through-ground flow, even if a dike or retaining structure is provided to control the surface (overground) flooding. It must be emphasized that this interpretation is based on many simplifying assumptions and the field data available is insufficient to perform any detailed analyses. The analysis only provides an indication of the nature of the problem in Simonds and is not corroborated by appropriate field data.

In order to control this flow through pervious soils, a sheet pile wall or a similar cutoff structure would be required. For the benefit-cost analysis, it is necessary to know the depth of penetration into the ground of the sheet piling (embedment) to effectively control the through-ground flow during flooding events. For preliminary estimation purposes, it is recommended that the sheet piles be driven to approximately elevation 41.5 m (136.2 ft). This recommendation would have to be revised when adequate long term data is obtained on the interaction between the River and groundwater table.

Installation of sheet piling to at least elevation 41.5 m (136.2 ft) will have a long term permanent effect on the inland groundwater regime in the vicinity of the Saint John River. This aspect is also difficult to quantify at this time with the data

available. The consequences of forming an inland basin, must be reviewed in detail prior to the final design and construction.

In order to better understand the rise in groundwater table during high water levels in the River, it is strongly recommended that a monitoring system of wells perpendicular to the River should be installed. The groundwater table and the water level in the River should be monitored simultaneously over a long period of time to obtain statistically significant data. These data are mandatory to obtain a quantified Engineering assessment of the River/groundwater interaction for future Engineering Works.

5.3 Embankment Stability Guidelines

Sub Surface Surveys has prepared a series of soil parameter guidelines which are suggested to be used in evaluating the slope stability within the Study Area. These parameters are prepared from soil mechanics principles and are presented as an aid to assist non-geotechnical reviewers. The procedures are not intended to replace rigorous Engineering investigations and analyses, rather, they are intended to be a guide for first approximation when more detailed investigations are not available.

These guidelines are based on the Unified Classification System and were developed utilizing chart solutions for slope stability, published empirical relationships and experience.

5.4 Embankment Stability

The slopes in the Study Area are affected by variations in the River and groundwater levels, and it is important to evaluate the effects of these events on the overall slope stability.

These slopes have been analyzed in a generic fashion in an attempt to provide a series of field charts to enable the non-

geotechnical Engineer to reasonably assess a slope condition in the field with a reasonable degree of accuracy, but more importantly, with an acceptable assurance that the results will be reproducible between sites and will provide good working guidelines.

The basis for the model developed to construct these generic stability charts was a paper by Bishop and Morgenstern (1960). The most critical factors to be reviewed in terms of the slope stability by this generic stability chart method are those of slope angle and pore pressure response.

6.0 BANK EROSION - SAINT JOHN RIVER

An examination of the entire length of the riverbanks within the Study Area was performed. Areas of noted instability as defined by fallen trees, sloughed crest of slopes, or gravel talus failures were defined as potential sources of future instability problems. In addition to the noted unstable areas, areas which had been re-engineered and constructed to achieve stability were also identified as bank erosion sites.

A video tape file of the entire Study Area was compiled and provided to the Working Group under separate cover.

6.1 Sites

A total of six (6) sites were identified in the Simonds Study Area. The majority of the identified bank erosion sites were classified as being non-critical in nature. One (1) site (Site 44) was identified as critical and in need of immediate action.

Map 6-1 indicates in general terms the position of the sites relative to the small scale mapping of the area.

Erosion at the majority of the sites reviewed was the direct result of natural stream bank movement due to natural forces and was noted in areas where forest or farmland was affected by loss of ground and no structures or public utilities were directly affected.

The critical area was that site which affected structures, access routes or other real property.

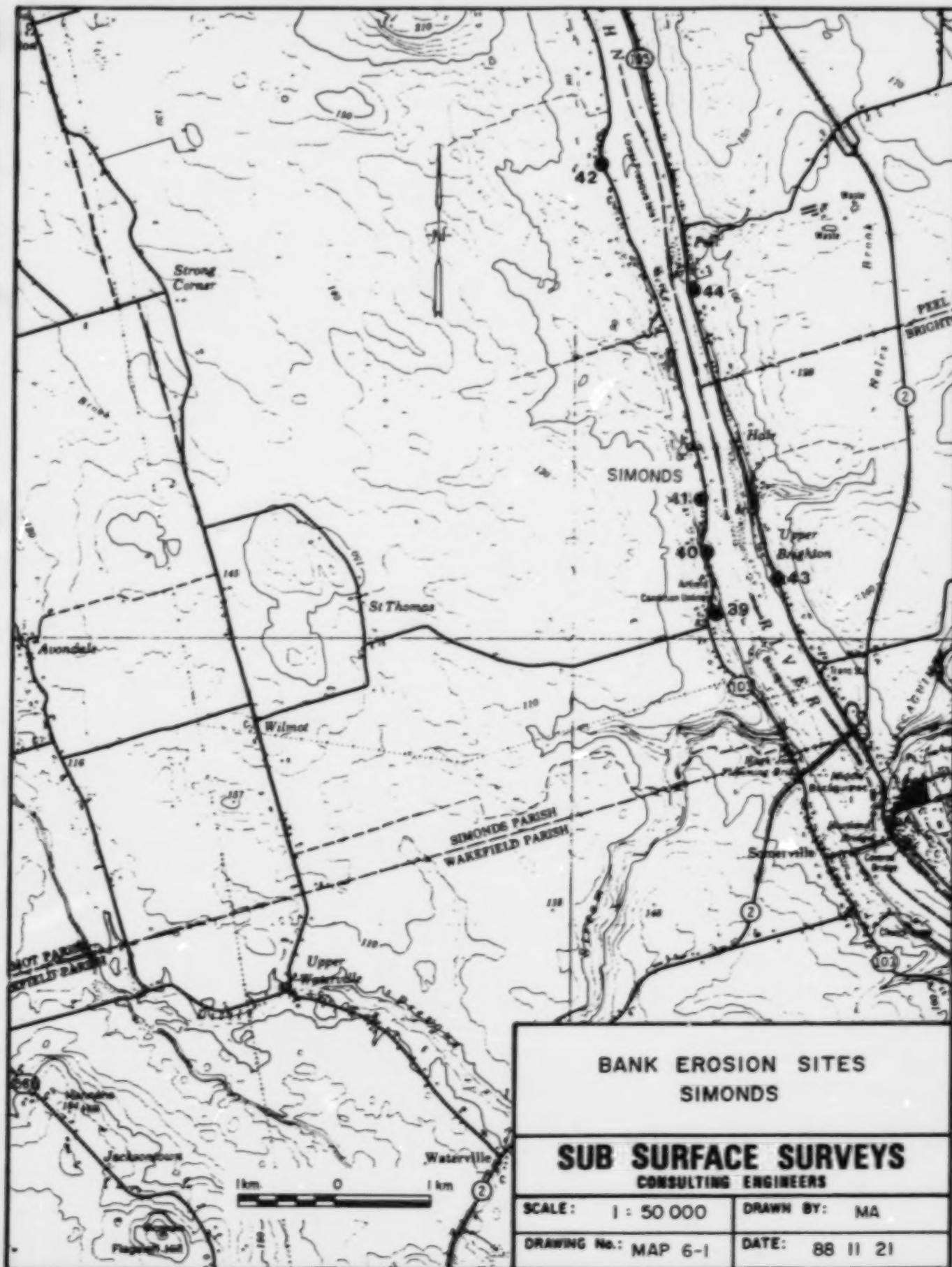
The site identification tables in the Technical Background Report present each site in terms of:

- * height of the slope, defined as the above water portion.
- * the estimated lineal metres of affected area.

6.2 Remedial Costs

The costs associated with remedial action were reviewed based on three (3) general design considerations as follow.

- * Regrade the slope to a shallower angle of repose (3 H to 1 V minimum) and thus force improved stability using a cost effective material (ie. locally available pit run gravel). Such slopes however, would still be subjected to normal erosional forces and would have a tendency to steepen at the toe of slope (point of erosion and mass transport) and thus become unstable and deteriorate with time.



- Regrade the slopes to a shallower angle of repose (2 H to 1 V minimum) using a high quality, 300 mm (12 inch) minus, coarse rock fill. This material would be expensive and might only be appropriate for the more critical areas where the benefits of remedial actions would be well defined. This action could be designed to provide a long term stable solution.
- Regrade the existing slopes by reshaping the in situ material to provide a flatter slope aspect to the River. This solution is similar to the first solution with the exception that imported borrow would not be required and therefore would be very cost effective. This solution again would be subject to deterioration with time, and could not be implemented where water depths in the River exceed 1 m (3.3 ft).

In reviewing the bank erosion sites no costs have been applied to land purchase as it was found that a wide variation in prices predominated, therefore, the estimate of a narrow riverbank acquisition would likely be inaccurate to the point of being misleading.

Costs for remedial action have been prepared in a general format, with the results presented in the Technical Background Report and are shown as a cost per lineal metre based on the overall slope height.

7.0 REMEDIAL MEASURES

The high water levels from the 1986 flood produced damage related to both the overland flow of water and to the movement of water through the permeable subsurface layer. The latter flow caused basement flooding and foundation damage in areas which may not have been directly damaged by the overland flows. The rapid

increase in the groundwater level due to the flood also contributed to the instability of the riverbanks and to slope failures in some places.

The scope of work for this Study requires that methods of mitigating the damage from future flooding up to levels equal to the 1986 flood be investigated. The remedial measures to be investigated must address the particular problems of the area related to the permeable subsurface layers and to the nature of the flooding. The ice jam type of flood results in an extremely rapid rise in water level, which can reduce the effective time available to take any emergency action in the face of rising flood waters.

7.1 Options for Remedial Measures

The identification of remedial measures which will act as effective flood control options, appropriate to the Study Area requires the consideration of a large number of possible measures from which a list of practical measures may be drawn. A number of studies have been done to consider ways of protecting buildings from flooding. These were examined to produce a list of measures to be examined in detail for Simonds. The range of potential solutions include using Engineering Works to protect large areas of the floodplain from flooding, as well as floodproofing which is aimed at individual structures. This section considers both types of protection.

The focus of protection from flood damage, as identified by previous studies, must address three main causes of the damage:

- flooding overland;
- flooding by rising groundwater levels; and
- bank erosion and instability.

The objective of this study is to produce designs for remedial measures only in sufficient detail to allow costs to be estimated. Due to the large number of structures to be protected and the large area of riverbank to be investigated for stability it is necessary that most of the recommended measures be generic in nature. Thus, they may not address the specific aspects of an individual structure, but may be applicable to a range of similar structures.

Structural remedial measures which will reduce or eliminate the flooding of large sections of the floodplain are termed Engineering Works. These can include dikes which will hold the flood water within the normal riverbanks or flood control structures which can directly control the flow of water in the River and can store or divert water so it does not flood an area. Floodproofing is the reduction or elimination of flood damage to individual properties and is considered applicable on a single structure or property basis. Floodproofing can include the raising of structures or the waterproofing of basements.

Table 7-1 presents the list of remedial measures which are examined. For these measures, conceptual designs are derived in sufficient detail to allow an approximate cost estimate to be obtained. The resulting cost estimates are used in the economic analysis to help determine if the measures are economically feasible as a solution to the problem of flooding in the Study Area.

TABLE 7-1
Selected Alternative Remedial Measures

Structural Measures

- Floodproofing
- Dikes
- Floodwalls
- Raising Roads
- Relocation
- Channelization
- Bank Stabilization
- Backflow Prevention Valves

Non-Structural Measures

- Floodplain Zoning
- Flood Forecasting
- Land Purchase

7.2 Description of Selected Alternatives

7.2.1 Floodproofing

There are three main categories of floodproofing measures for structures: permanent, contingency and emergency. Permanent measures include raising of buildings and do not require a flood forecast or any action to be taken to be effective. Contingency measures include watertight shields for doors or windows, and require some action prior to flooding and usually a warning to be effectively implemented. Emergency measures may include sandbagging or evacuation and require adequate warning time of the flood as well as a fully operational emergency preparedness plan.

Permanent floodproofing is the most effective method of alleviating flood damage. Typical floodproofing methods are illustrated in Figure 7-1.

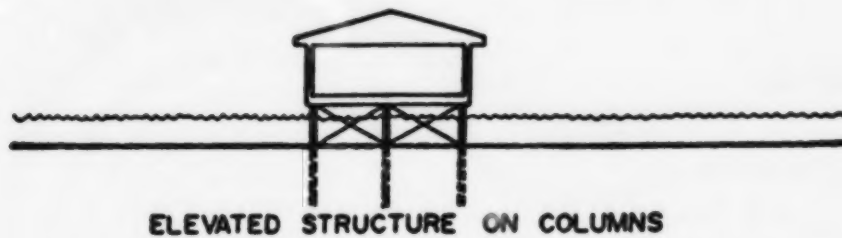
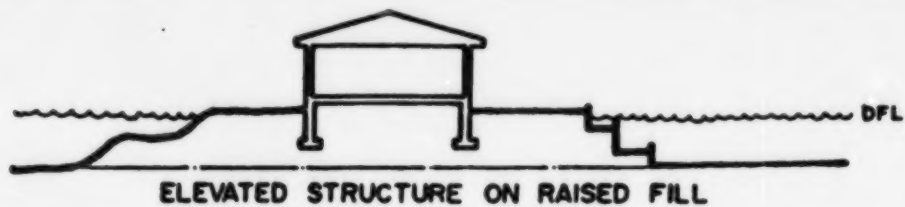
The option of floodproofing can be considered alone or in conjunction with other remedial measures which may offer only partial protection to the area. The level to which the structures must be protected is to be taken as that of the 1986 flood. The flood waters reached a maximum of 1.5 m (4.9 ft) above the first floor elevation in some areas, requiring extensive floodproofing.

Floodproofing for the Study Area considered only the measures which can be applied by retrofitting. This study does not address methods of construction of new buildings which may be built in the floodplain at a later date. It has been assumed that any new structure built in an area affected by flooding will be adequately floodproofed.

Only permanent floodproofing measures which by definition require no action at the time of flooding to be effective were considered. The warning time cannot be assumed to be sufficient to implement contingent measures such as the installation of flood doors or closing flood barriers. Closures and seals are most effective in new construction and require a warning time of 5 to 8 hours to be properly installed (FEMA, 1985).

7.2.2 Dikes

Dikes have a long record of use for flood control under open water conditions. Required dike elevations can be determined for open water levels with reasonable confidence. Under ice jam flooding conditions, dikes can be used to keep flood waters and ice out of a damage prone area. The major difficulty is the



SOURCE: KOZAK, 1987

FLOODPROOFING ALTERNATIVES

SUB SURFACE SURVEYS CONSULTING ENGINEERS

SCALE: N. T. S.

DRAWN BY: MA

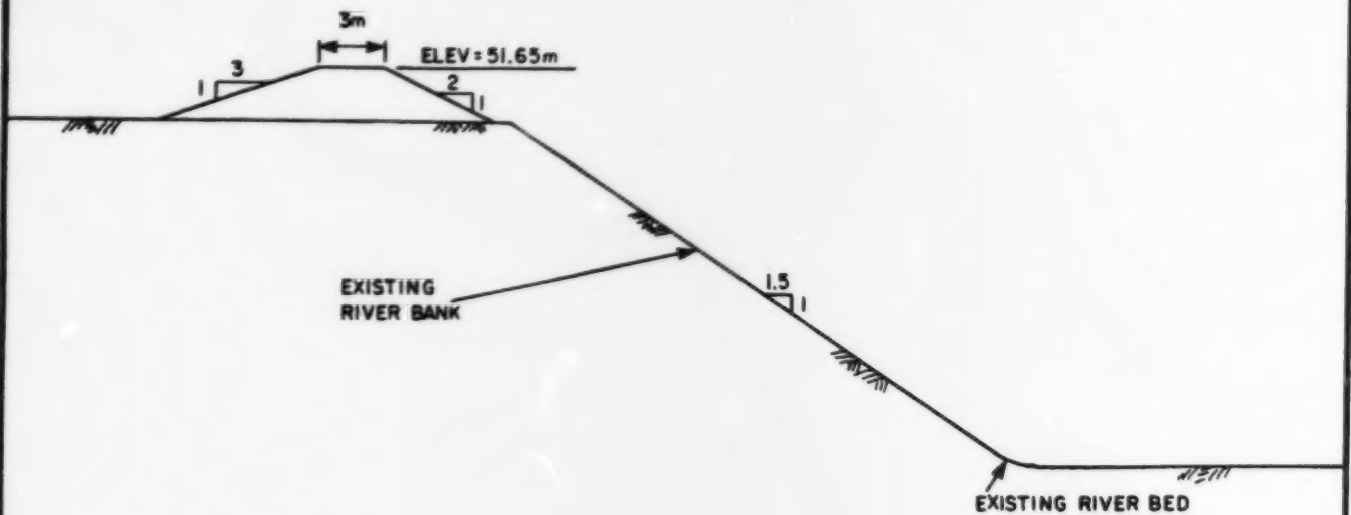
FIGURE No. 1 7 - 1

DATE: 88 11 15

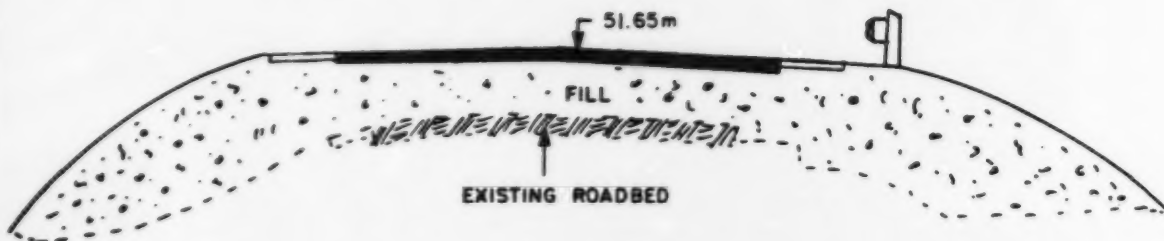
determination of the appropriate design level for the ice jam event. Placement of dikes along the riverbanks could eliminate the spreading of the flood waters over the wide area of the floodplain and cause an increase in the flood peak. In the Simonds area this is not expected to be a major problem since this can presently only occur at extremely high water levels and elimination of the over bank area should not have a significant impact on the maximum flood level.

In addition to preventing the inundation of the area by overland flow, the dike would also prevent the outflow of surface runoff. The design must consider how to reduce or eliminate the accumulation of seepage and/or internal surface runoff on the dry side of the structure. If adequate space is not available to temporarily store all seepage and runoff that is likely to occur at the site, excess water must be drained to low lying sump areas and pumped to the wet side of the dike. During non-flood situations, surface runoff within the protected area may be discharged through drainage pipes or culverts that extend through the dike. These outlets must be equipped with an automatic check valve to prevent backflow during a flood.

The problem of seepage of groundwater was reviewed and it is apparent from the analysis that a dike will act to hold back the surface water flow while still allowing some through-ground flow to occur. The level of the groundwater surface will be maintained at about the ground surface level, with seepage up to the surface occurring in some low lying areas. The earth dike must therefore be used in combination with floodproofing and reinforcement of basements. Figure 7-2 illustrates a typical dike section.



TYPICAL DIKE SECTION



TYPICAL RAISED ROAD SECTION

**DIKE AND RAISED ROAD
DETAILS**

**SUB SURFACE SURVEYS
CONSULTING ENGINEERS**

SCALE: N.T.S.

DRAWN BY: MA

FIGURE No. 7-2

DATE: 88 11 21

7.2.3 Raising Roads

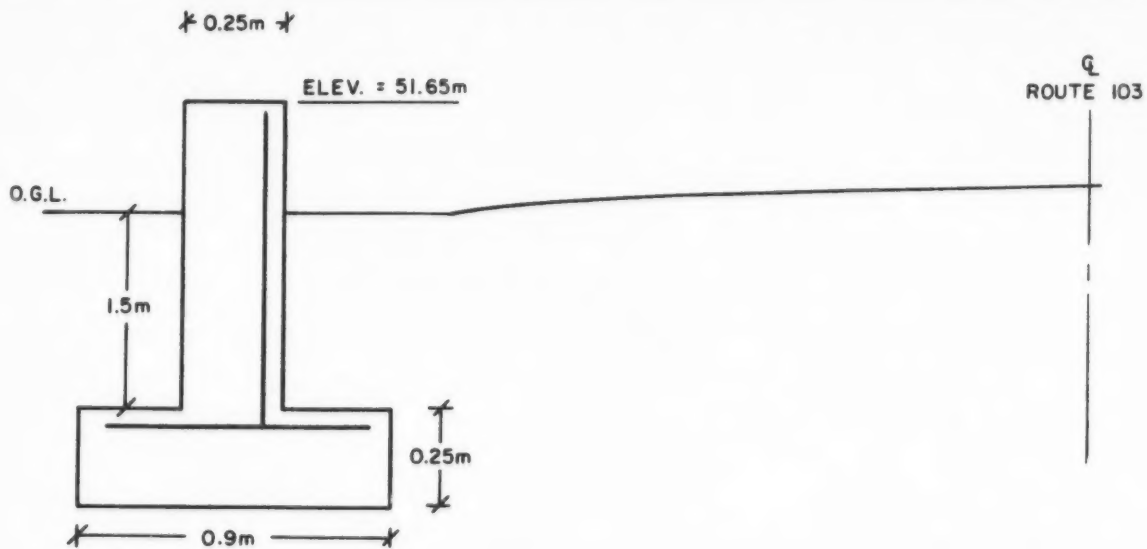
The advantage of raising roads is that an existing structure is used, which would be beneficial in areas of limited available land (Figure 7-2). The flooding in Simonds requires that the road be raised by up to 3.5 m (11.5 ft) in places, although most of the raising would be limited to less than 1.5 m (4.9 ft). This would require ramping of all side roads or driveways entering the highway. This would drastically change the character of the main highway in Simonds, and it is expected to meet with opposition from residents.

7.2.4 Floodwalls

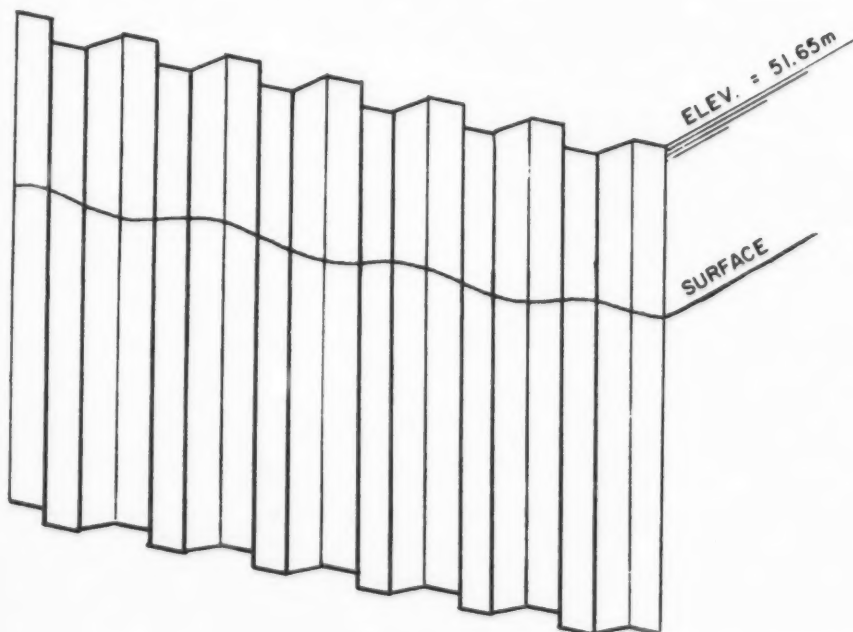
A floodwall is very similar to the dike in function. It prevents overland flow from entering the flood risk area, thereby eliminating the damage from flooding. A floodwall may be a concrete retaining structure or a sheet pile wall. It will generally be much smaller in width than an earth dike, and therefore reduce the amount of land which must be used for the construction of flood control measures. The floodwall will cut off the drainage of surface water and will require culverts with backflow prevention valves, similar to the earth dike. Figure 7-3 illustrates some typical floodwall sections.

The floodwall will not normally provide a cut off to the through-ground flow and will therefore be subject to the same constraints as the dike for consideration of its effectiveness. The sheet pile floodwall, however, could be driven to an adequate depth to provide a cutoff to the through-ground flow.

A floodwall will cut off the view of the river if it is of sufficient height, and it may not be aesthetically acceptable. The floodwall required in Simonds will reach as much as 2.0 m (6.1 ft) in height.



CONCRETE FLOODWALL



**SHEETPILE
FLOODWALL**

FLOODWALL DETAILS

**SUB SURFACE SURVEYS
CONSULTING ENGINEERS**

FIG. No.:	7 - 3	DRAWN BY:	M.S.
SCALE:	N. T. S.	DATE:	88 11 21

7.2.5 Relocation

A structure which is completely removed from the flood prone area to a location free of flooding will have all possible flood damage eliminated. Some structures are easier to relocate than others, depending on size and style of the house. For large houses, cutting of the structure may be necessary to allow for transportation on available routes. Very old structures, such as those found in parts of Simonds may not be strong enough to withstand relocation. Commercial structures may be very difficult to relocate, depending on their function and size. The costs associated with relocation are quite high, and must include the cost of the purchase of a new, serviced lot and the construction of a new foundation, in addition to the costs of removal from the old site and transportation of the structure.

Relocation of houses requires the cooperation of the residents, and can be very unpopular since it will break up neighbourhoods and change access to services and facilities within the local area.

7.2.6 Channelization

Channelization is the modification to the normal River channel through excavation or dredging of the channel. This acts to lower the water levels when an ice jam does occur, since the maximum level of a jam is related to channel flow area. Channelization can also act to reduce the lodgement points and promote the conveyance of ice in the River, preventing the stoppage of an ice run.

The reach from Beechwood Dam to Woodstock presents a number of known and potential lodgement sites for ice jams. These cannot be reliably identified for channelization, nor can it be

ascertained that the improvement of the River at a past lodgement site will be effective in preventing a future ice jam. Therefore, channelization will not be considered as an effective remedial measure for implementation in Simonds.

7.2.7 Floodplain Zoning

Restriction of development in the flood prone areas through the instigation of floodplain zoning legislation can prevent further development in the floodplain. This will cause the loss of some development opportunity, but will prevent some of the increase in the damages associated with flooding.

The costs associated with changes to zoning in an unincorporated area are very difficult to quantify. These costs represent potential loss to future development, and therefore do not compare directly to structural remedial measures suggested for which there is an immediately apparent cost and benefit.

7.2.8 Flood Forecasting

The objective of a flood forecasting program is to predict the rate and magnitude of the discharge and water level rise in a river. A River Forecast Centre has been set up to provide a forecast of the flood events on the Saint John River associated with the open water conditions. Ice jam events cannot be forecast as current technology cannot predict where or when they will occur. The Centre does observe ice conditions and issues warnings to ice jam prone areas.

The difficulty in predicting ice jams means that there must always be a high degree of awareness by the residents of the existing conditions during the time of spring breakup. It will not be possible to issue a warning very much in advance that the

water is rising, and the warning will not be able to give the maximum water level to be expected. These conditions are very dependant on the ice volumes present in the River at the time of breakup, the flows, the type and thickness of ice and the location of the jam lodgement. Even if all the details of these parameters were available, the ice jam limits could still not be predicted with the current knowledge of ice jam formation.

For these reasons it is recommended that local residents continue to provide river observations to the River Forecast Centre. The Centre should continue to issue warnings concerning ice movements. It is important to maintain the public awareness and interest in the area. The 1986 ice jam flood is still very fresh in peoples minds, but the next major flood may not occur for many years and peoples memories of 1986 may tend to fade somewhat if the importance of being alert is not reinforced every spring.

7.2.9 Bank Stabilization

After the flooding of 1986, locations of severe bank erosion were noticed in addition to the damages to roads and structures from the flow of water. The assessment of the benefit-cost ratios of stabilizing riverbanks subject to a natural erosion process is difficult, since the value of land which is being lost can be quite small in comparison to the cost of the remedial works. For aesthetic and safety reasons, stabilization of banks in rural areas may be advisable. Within a community, erosion and destabilization of riverbanks may pose an immediate threat to a structure, and therefore it would be more beneficial to repair these slopes.

7.2.10 Backflow Prevention Valves

The drainage of runoff in the Simonds area is accomplished by a series of four (4) culverts which empty directly into the Saint John River. All of the outlets are well below the flood levels in the River. Backflow through these culverts provide the first

inlet for flood waters to enter the area. The addition of backflow valves on all culverts could immediately provide protection from overland flow for flood levels in the River up to a maximum of about 48.5 m (159.1 ft.), the height of the existing banks.

In order to provide complete protection, however, the backflow valves must be used in conjunction with other remedial measures which give full protection from the maximum flood level in the River.

7.2.11 Land Purchase

In some areas it may not be feasible to implement any remedial measure to prevent damage from flooding. The rural areas along the River, for example, may only have a small land value, but would require a very expensive structure to provide full protection. In these cases, the land in question could be purchased from the owner so that it will not be of concern, and allowed to erode or flood naturally.

7.3 Simonds Remedial Measures

The following specific remedial measures are considered for the Study Area:

- | | |
|----------------|---|
| ALTERNATIVE 1: | EARTH DIKE THE ENTIRE LENGTH OF SIMONDS, FLOODPROOF ALL BASEMENTS. |
| ALTERNATIVE 2: | CONCRETE FLOODWALL THE ENTIRE LENGTH OF SIMONDS, FLOODPROOF ALL BASEMENTS. |
| ALTERNATIVE 3: | SHEETPILE FLOODWALL THE ENTIRE LENGTH OF SIMONDS, FLOODPROOF ALL BASEMENTS. |

- ALTERNATIVE 4: SHEETPILE FLOODWALL THE ENTIRE LENGTH OF SIMONDS DRIVEN TO CUTOFF DEPTH.
- ALTERNATIVE 5: RAISE ROADS ALONG THE ENTIRE LENGTH OF SIMONDS, FLOODPROOF ALL BASEMENTS.
- ALTERNATIVE 6: RAISE ROADS ALONG THE ENTIRE LENGTH OF SIMONDS, FLOODPROOF ALL BASEMENTS AND RAISE ALL STRUCTURES WHICH WERE SUBJECT TO OVERLAND FLOW IN THE 1986 FLOOD.
- ALTERNATIVE 7: ELEVATE ALL STRUCTURES DIRECTLY AFFECTED BY OVERLAND FLOODING, FLOODPROOF ALL BASEMENTS AFFECTED BY THROUGH-GROUND FLOW.
- ALTERNATIVE 8: ELEVATE ALL STRUCTURES DIRECTLY AFFECTED BY OVERLAND FLOODING TO A DEPTH OF 1 M OR LESS, OTHER STRUCTURES AFFECTED BY OVERLAND FLOW WOULD BE RELOCATED, FLOODPROOF ALL BASEMENTS AFFECTED BY THROUGH-GROUND FLOW.
- ALTERNATIVE 9: ELEVATE ALL COMMERCIAL STRUCTURES DIRECTLY AFFECTED BY OVERLAND FLOODING, RELOCATE ALL RESIDENTIAL STRUCTURES AFFECTED BY OVERLAND FLOW, FLOODPROOF ALL BASEMENTS AFFECTED BY THROUGH-GROUND FLOW.
- ALTERNATIVE 10: RELOCATE ALL STRUCTURES DIRECTLY AFFECTED BY OVERLAND FLOODING, FLOODPROOF ALL BASEMENTS OF STRUCTURES AFFECTED BY THROUGH-GROUND FLOW.

Map 3-1 indicates the locations of the various proposed remedial measures specific to the Study Area.

7.4 Basis of Cost Estimate

The cost estimation for the proposed remedial measures has been carried out using 1988 cost figures. The costs for Engineering

Works, such as dikes and floodwalls are based on quantity take-offs from conceptual layouts of the remedial measures.

The assessed value of structures in the Study Area was based on information compiled during the Phase I study (Gemtec, 1988). The average assessed value for structures in Simonds was found to be \$39,904.

The assessed value in Simonds appears to be low, which may reflect the economic nature of the area and the relative predominance of older structures. The assessed value, however, has been used in this study, in order to provide a basis for comparison as has been done in other evaluations of floodproofing measures (Kozak, 1987, MacLaren, 1978).

Table 7-2 summarizes the cost estimates for each of the remedial measures which were considered for Simonds.

Table 7-2

Summary of Cost Estimates of Remedial Measures

Type of Measure	Simonds
1) Earth Dike - plus protect basement	\$530,000
2) Floodwall - concrete retaining wall + protect basements	\$1,800,000
3) Floodwall - sheet pile retaining wall + protect basements	\$3,400,000
4) Floodwall - sheet pile retaining wall to cutoff	\$14,590,000
5) Raise Roads - plus protect basements	\$1,840,000
6) Raise Roads - plus protect basements + elevate all structures	\$2,040,000
7) Floodproof - elevate all structures affected by overland flow + protect basements	\$530,000
8) Floodproof - raise to max of 1 m + relocate + protect basements	\$660,000
9) Floodproof - raise commercial buildings only, relocate residents	\$1,050,000
10) Relocate - relocate all structures affected by overland flow + protect basements	\$1,180,000

8.0 ECONOMIC EVALUATION

The Simonds Local Service District was subjected to severe flooding both from overland flow and groundwater infiltration in April 1986 as a result of an ice jam which resulted in damages of \$244,000.

Benefit-cost analysis is a standard economic technique for estimating the net gains to society from a proposed investment. In this study it is used to rank the ten (10) alternative remedial actions.

Flood frequency was found to have a significant impact on benefit-cost ratios but not on the ranking of the ten (10) alternative remedies under study. The frequency with which the severe 1986 event takes place was varied between 5 and 200 years. These estimated frequencies were used to generate expected annual damage figures for commercial structures. Residential damages were calculated in the same manner, with the Paragon (1985) program allowing as additional inputs the duration of the flooding, warning time, and the velocity of the flood waters. Adjustments were also made for regional differences in consumer prices and property values by calibrating to the damage claims from the 1986 flood.

Some measures, such as dikes or sheetpile floodwalls, would keep out all of the flood waters and result in a 100 percent reduction in damage. Other measures, such as the floodproofing of individual structures, would still permit losses associated with clearing debris and foregone income, estimated at 66% of the flood damage.

In any benefit-cost analysis one must propose reasonable assumptions upon which to base estimates of future benefits and damages and the assumptions made in this analysis are detailed in the Technical Background Report.

The estimated benefit from each remedial action is the present value of the difference between the expected annual damage without the measure, and the expected annual damage under the remedy.

The benefit-cost ratios for each remedy are given by the present value of the expected benefit stream created by the intervention, relative to the present value of the expected stream of future costs. Since costs are assumed to be incurred in the initial

year of the project and subsequent operating and maintenance costs are assumed to be insignificant, the benefit-cost ratios are presented as the present value of the expected benefit over the initial cost outlay.

8.1 Benefit-Cost Ratios - Remedial Measures

Table 8-1 presents the benefit-cost ratios for the ten remedies under consideration. At an interest rate of 10%, no options yield a benefit-cost ratio of greater than unity. The ranking of the measures by benefit-cost ratios suggest that the earth dike, (1), yields the greatest benefit per dollar in costs (0.25). This is followed by the floodproofing option (7), which includes elevating all overland flow affected structures and floodproofing basements, with a benefit-cost ratio of 0.15. The third ranked measure, which has a benefit-cost ratio of 0.12 is the floodproofing option (8), and includes raising structures to a maximum of 1 metre (3.3 ft) and floodproofing basements and some relocating.

Table 8-1 Benefit-Cost Ratios				
Measure	i=0.05	i=0.10	i=0.15	Rank
1) Earth Dike	0.47	0.25	0.17	1
2) Floodwall	0.14	0.08	0.05	6
3) Floodwall	0.07	0.04	0.03	9
4) Floodwall	0.02	0.01	0.01	10
5) Raise Roads	0.13	0.07	0.05	7
6) Raise Roads	0.12	0.07	0.04	8
7) Floodproof	0.28	0.15	0.10	2
8) Floodproof	0.23	0.12	0.08	3
9) Floodproof	0.14	0.08	0.05	5
10) Relocate	0.21	0.11	0.08	4

Note: (1) i = interest rate

(2) Assumed flood frequency of 1 in 100 years (Base Flood)

8.2 Incremental Benefit-Cost Ratios

Table 8-2 summarizes the benefit-cost ratios in total, and provides information on the incremental benefit-cost ratio, defined as the additional benefits returned by an increment of cost above the last acceptable alternative. The incremental benefit-cost ratio is used to examine the marginal benefit relative to the marginal cost to ensure that benefits rise by more than costs when the next largest project (as measured on a cost basis) is undertaken. If the increase in benefits falls short of the increase in the cost of the remedial project, the remedy under consideration is not as efficient an allocation of societies' resources as was the previously considered remedial action.

The least expensive remedy is an earth dike (1) at an estimated cost of \$530,000, with benefits estimated in present value terms at \$134,147. As compared to doing nothing, the earth dike does not provide an increase in benefits that exceeds the increase in costs

8.3 Evaluation

The reported analysis has investigated the relative merits of ten remedial measures aimed at alleviating damages due to flooding in Simonds. Estimates of the potential benefits and costs were identified, and the benefit-cost ratios were examined to determine how robust they were to variation of the discount rate and the flood return period.

TABLE 8-2
Incremental Benefit-Cost Ratios

Measure	Present Value of Expected Benefits	Costs	Incremental Benefit	Incremental Costs	Total B-C Ratio	Incr. B-C Ratio
1	\$134,100	\$530,000	\$134,100	\$530,000	0.25	0.25
7	\$80,500	\$530,000	-\$53,600	\$0	0.15	0.00
8	\$80,500	\$660,000	\$0	\$130,000	0.12	0.00
9	\$80,500	\$1,050,000	\$0	\$390,000	0.08	0.00
10	\$134,100	\$1,180,000	\$53,600	\$130,000	0.11	0.41
2	\$134,100	\$1,800,000	\$0	\$620,000	0.08	0.00
5	\$134,100	\$1,840,000	\$0	\$40,000	0.07	0.00
6	\$134,100	\$2,040,000	\$0	\$200,000	0.07	0.00
3	\$134,100	\$3,400,000	\$0	\$1,360,000	0.04	0.00
4	\$134,100	\$14,590,000	\$0	\$11,190,000	0.01	0.00

Note: * Remedial measures are listed by increasing cost.
 * Assumed interest rate 10%
 * Assumed flood frequency of 1 in 100 years (Base Flood)

The results of benefit-cost analyses based on an interest rate of 10% and a base flood of 1 in 100 year return period are presented in Table 8-3. The estimated cost for the ten (10) proposed remedial measures are also shown.

Table 8-3
Cost Estimates and Benefit-Cost Ratios for Remedial Measures

Remedial Measure	Cost	Benefit-Cost Ratio
1) Earth dike	\$530,000	0.25
7) Elevate overland flow affected structures	\$530,000	0.15
8) Elevate to max of 1 m, relocate others	\$660,000	0.12
10) Relocate overland flow affected structures	\$1,180,000	0.11
9) Elevate commercial, relocate others	\$1,050,000	0.08
2) Concrete floodwall	\$1,800,000	0.08
5) Raise roads	\$1,840,000	0.07
6) Raise roads and raise structures	\$2,040,000	0.07
3) Sheetpile floodwall	\$3,400,000	0.04
4) Sheetpile floodwall to cutoff	\$14,590,000	0.01

Note: * Remedial measures listed by decreasing benefit-cost ratio
* Interest reate = 10%, base flood of 100 year return assumed

9.0 CONCLUSIONS

The Technical Background Report details the methodology used in defining the aspects of the flooding and associated remedial measures that would be appropriate for Simonds.

The Summary Document presents the synopsis of the findings of the Technical Background Report. It is suggested that the complete documentation be reviewed as additional actions and supporting data are included that may be significant.

PLANNING

- 1) It is recommended that flood zones be established and controlled by enactment of Flood Risk Area Guidelines for Simonds.
- 2) Incentives should be considered for the existing residents to assist them in either floodproofing or relocating.
- 3) Development should be discouraged within the defined flood zones.
- 4) Official disclosure of the flood risk should be made to notify potential developers within the flood risk area.

HYDROTECHNICAL

- 5) Culverts have sufficient capacity under backflow conditions to contribute significantly to flooding.

- 6) It is concluded that culverts should be blocked by flap gates, to protect against the inward flow during flooding.

GEOTECHNICAL

- 7) It was concluded that the flood water movement in Simonds by through-ground flow could be a significant factor in the flooding.
- 8) It is recommended that a study should be undertaken to define the response of the groundwater table in relation to the rise in the River water level.
- 9) Six (6) sites of riverbank erosion were identified and it was concluded that one (1) site is in need of immediate action.
- 10) Remedial measures recommended for slope stabilization are presented.

REMEDIAL MEASURES

- 11) A number of potential remedial measures for flood protection were reviewed from which ten (10) selected measures are recommended and were analyzed in detail.

ECONOMICS

- 12) The selected remedial measures are presented in Table 9-1 with the associated costs and the ranking based on the benefit-cost ratios developed.

Table 9-1
Cost Estimates and Benefit-Cost Ratios for Remedial Measures

Remedial Measure	Remedial measures Cost	Benefit- Cost Ratio
1) Earth Dike	\$530,000	0.25
7) Elevate structures affected by overland flow	\$530,000	0.15
8) Elevate to max of 1 m, relocate others	\$660,000	0.12
10) Relocate structures affected by overland flow	\$1,180,000	0.11
9) Elevate commercial, relocate others	\$1,050,000	0.08
2) Concrete floodwall	\$1,800,000	0.08
5) Raise roads	\$1,840,000	0.07
6) Raise roads and elevate structures	\$2,040,000	0.07
3) Sheetpile floodwall	\$3,400,000	0.04
4) Sheetpile floodwall to cutoff	\$14,590,000	0.01

Note: * Remedial measures listed by decreasing benefit-cost ratio.
* Interest rate = 10%, base flood of 100 year return assumed.

13) It is concluded that:

- ° Maximizing the dollar value of benefits per dollar spent on costs leads to the selection of the remedial measure of an earth dike, as does the objective of maximizing the net present value of the remedial project.
- ° No measure is recommended on the basis of the benefit-cost analysis.

- If the earth dike is excluded on the grounds it carries negative externalities, the most efficient remedial measure becomes the floodproofing option of elevating all structures which were affected by overland flow.
 - The ranking of measures is insensitive to the choices of the discount rate and the flood return period.
 - The construction of the remedial measure will have positive effects on employment and incomes in the Province.
- 14) Non-economic issues such as aesthetics, social, cultural and planning considerations may alter the ranking of the remedial measures which have been assessed from a solely economic perspective.

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**MAPS
NOT
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**CARTES
OMISES**